Journal of Coastal Research	9	1	104–111	Fort Lauderdale, Florida	Winter 1993

Evolution of the Caspian Sea Coasts Under Conditions of Sea-Level Rise: Model for Coastal Change Under Increasing "Greenhouse Effect"

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ABSTRACT

IGNATOV, Y.I.; KAPLIN, P.A.; LUKYANOVA, S.A., and SOLOVIEVA, G.D., 1993. Evolution of the Caspian Sea coasts under conditions of sea-level rise. *Journal of Coastal Research,* 9(1), 104–111. Fort Lauderdale (Florida), ISSN 0749-0208.

Since 1978 the Caspian Sea level rose by 1.5 m. The coastal zone response to this modern transgression is a natural model of the possible future behavior of the World Ocean coasts due to the "greenhouse effect." Around the Caspian Sea there are several types of response. The major control of the coastal zone behavior under sea-level rise is the offshore slope: the steeper the slope the higher the zone of nearshore erosion is shifted up the coastal zone profile and towards the land. As a whole, the replacement of a regressive regime by a modern transgression since 1978 has resulted in widespread coastal erosion.

ADDITIONAL INDEX WORDS: *Transgression (modern), coastal types, erosion of coasts, offshore slope, Bruun rule.*

INTRODUCTION

The Caspian Sea is a unique water basin. It is totally isolated from the World Ocean level (W.O.L.). One of its peculiar features is a specific pattern of water level fluctuations. It is notable for very large fluctuations during the Quaternary (LEONTIEV *et al.,* 1977). And even in the 20th Century the fluctuations have been significant. A high level of the Caspian Sea (about 26 m below W.O.L.) was registered during most of the 19th Century, lasting until 1929 (LEONTIEV, 1988). Since 1929 the level dropped rapidly (Figure 1a) and by 1941 it had fallen by nearly 2 m. Drop of the water level continued, despite small oscillations (short-term rises in 1946–1948 and 1956–1958); by 1977 it had dropped down to −29.02 m; at that time the Caspian Sea level was the lowest for the last 200 years.

In 1978 the water level began to rise once more, and by 1990 reached −27.5 m (below W.O.L.): thus, in 12 years it rose by 1.5 m. The fluctuations of the Caspian Sea level are apparently explained by climatic factors and depend on the water budget of its basin: atmospheric precipitation and river discharge on the one hand, minus water loss by evaporation on the other. As was shown by LEONTIEV (1988), fluctuations of the Caspian Sea level follow cycles of 30–50 years (Figure 1b), *i.e.* they appear to correspond to the climatic cycles discovered by BRÜCKNER in the end of the last century. If this is true, one should expect a further rise of the sea level in the immediate future.

Because of this radical change of the physical situation, the replacement of a regression by a transgression regime, the dynamics of the Caspian coastal zone underwent a significant transformation (LEONTIEV and VELIEV, 1990). In the period of its fall in level in 1929–1977, there was accretion of land areas around the basin owing to drying out of shallow waters and to greater sediment accumulation, to growth of coastal aggradational features in both height and width. Accumulation was thus the dominant process at that time. However, the modern rise of sea level at the rate of 12.5 cm/year has led to a tremendous erosion of the coast.

Knowledge of these changes in the dynamics of the coastal zone in relation to sea-level rise is important not only for economic activities in the Caspian coastal area (though this is an urgent and pressing problem), but even more for understanding the evolution of the whole coastal zone of the World Ocean.

RESPONSE OF DIFFERENT COASTS TO THE CASPIAN SEA LEVEL CHANGE

Intensive erosion of coasts and consequently overall retreat of the shoreline is now a major

91107 received 15 November 1991; accepted in revision 24 July 1992.

current global trend, even where the land was formerly prograding. For several decades recently, coastal erosion has been increasing and affecting many of the world's coastal areas (BIRD, 1985). The major natural factor promoting erosion is the 1.5 mm/year rise of the W.O.L. However, some forecasts predict a sharp acceleration of sea-level rise in the nearest future as the result of increase in the atmosphere of CO_2 and other gases, and the consequent "greenhouse effect" and climate warming (BARTH and TITUS, 1984).

The processes that are taking place and will probably continue in the coastal zone of the World Ocean are as if modelled in the Caspian Sea in the course of its recent rapid transgression. It should be kept in mind, that besides the Caspian sea-level rise, intensive human activities are another factor that has promoted active change in the Caspian coastal zone. What has had the greatest influence on the development of these coasts was the acute reduction in the sediment input as a result of the construction of a system of hydroelectric and other facilities on the Volga, Kura, Ural, and other rivers of the Caspian basin.

The general conclusion is that the natural rise of the Caspian Sea level together with human economic activities have combined to produce a replacement of accumulative processes by erosional processes in the coastal zone. However, the patterns of change in the coastal zone depend largely on the coast type (LEONTIEV, 1988; IGNATOV *et al.,* 1989; LEONTIEV and VELIEV, 1990; IGNATOV *et al.,* 1990). The Caspian Sea coasts belong to several types: wave-generated accretionary coasts of different kinds (barrier coasts with lagoons, those with an adjoining depositional terrace and those with various other depositional features), erosional, deltaic, "drained" coasts, formed by wind-induced surges, *etc.* (Figure 2).

Deltaic coasts are extensive around the basin; these include deltas of the Volga and Ural rivers in the northern part, of the Terek and Sulak rivers in the north-west, of the Kura River in the south-west. Up until very recently, the above-named rivers were transporting large amounts of clastic material and were actively developing prograding deltas. For example, the sediment discharge of the Kura River reached 43 million metric tonnes/year. This process was intensified during the period of sea-level fall. Deltas were growing with the emergence of bars and banks, and mud flats that were transformed into islands and emerged terraces (LEONTIEV *et al.,* 1977). Before 1957 the

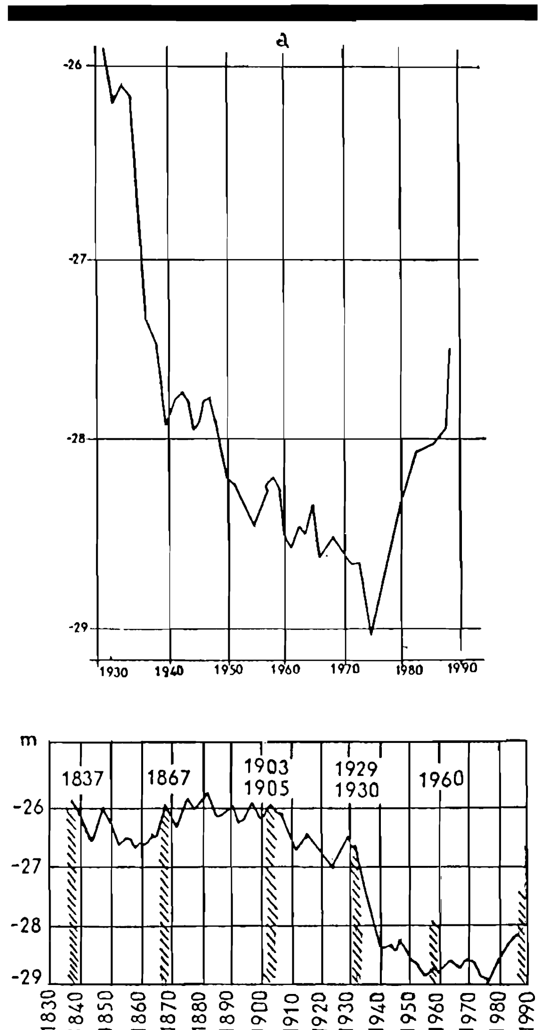
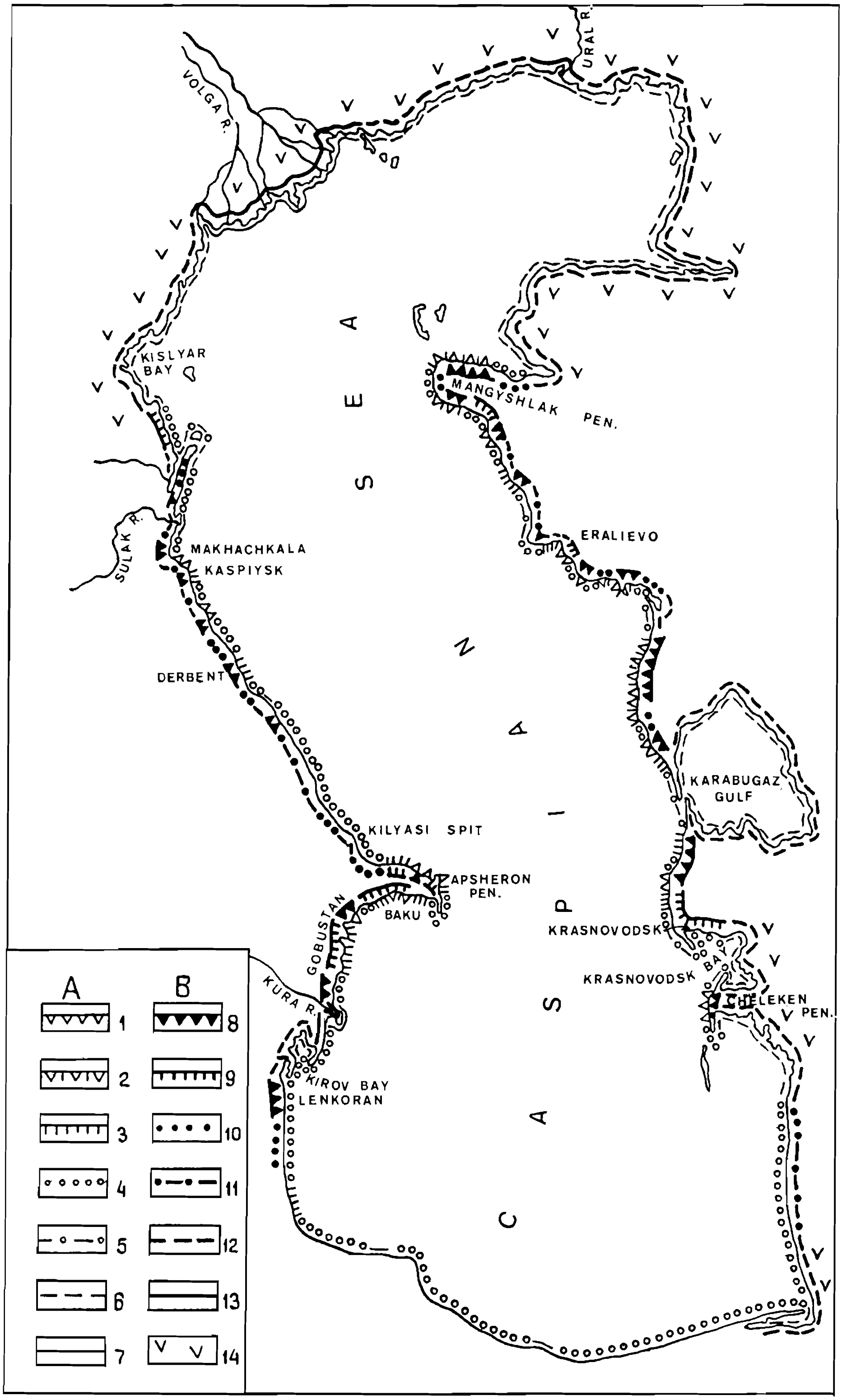


Figure 1. Changes of the Caspian Sea level: (a) changes of the sea level from 1929 to 1988; (b) periodicity of the Caspian sea-level changes during gauging observations (from 1837). "Brückner cycle" maxima of the level are shaded.

Kura delta was growing at the rate of 50–60 m/year, the northern edge of the Sulak delta at the rate of 100–200 m/year, and some parts of the Volga delta up to several km/year. In the northern Caspian Sea, in the deltaic areas of the Volga and Ural rivers the shoreline had advanced by tens and even hundreds of km since 1929. On the newly formed lands of the former sea floor roads and other economic and residential facilities have been constructed.

Erosion of the Caspian basin deltas, however, started even before the sea-level drop changed to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GOBUSTAN
KURA R.
KIROV BAY
LENKORAN
MANGYSHLAK PEN.
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the rising phase. In the late 1950–1960 decades many large-scale hydroelectric and irrigation projects were completed in the river valleys upstream. Around 1957 intensive erosion started in the eastern Kura delta, as a result of an abrupt reduction of sediment transport (by nearly 70%) by this river due to construction of the Mingechaur reservoir. In the 1960–1970 decades engineering activities (construction of canals) near the mouth areas of the Terek and Sulak rivers resulted in erosion of the delta coasts.

The modern rise of the Caspian Sea level has strongly accelerated erosion of all the deltas in the basin. In the northern Caspian Sea there was a significant inundation of the low deltaic shores. Simultaneously, erosion of the earlier aggradational features has been notable. At the present time, many islands near the deltas are subject to intensive erosion. The western shore of Malyi Zhemchuzhnyi Island is now retreating at 2–4 m/year; Morskoy Ochirkin Island, which in the 1970's was over 0.5 km long, was practically all eroded by the end of 1982.

There are vast, extremely shallow areas in the Caspian coastal zone that were drained at the time of the regression of the basin in the 1930–1970's and only partially flooded by the sea during periodic surges (which were up to 0.5–1 m high). These coasts with mud flats occur throughout the whole of the northern Caspian area, as well as surrounding Kirov Bay (in southern Azerbaijan), around Krasnovodsk Bay and south of the Cheleken Peninsula.

On the northwestern coast in the period of regression the rates of accumulation were very high. In Kislyar Bay the land advanced at the rate of up to 150–200 m/year; south of the bay it was 60–100 m/year, while north of it up to 700–800 m/year. In Kirov Bay wind-wave affected mud flats were 1.5 km wide, but at times of offshore winds the bay turned into a marsh. Along the eastern Caspian Sea the coast progradation during the sea level drop was less intensive. Even so, south of the Cheleken Peninsula the average rate of shore advance was 34–36 m/year (LEONTIEV *et al.*, 1977).

Replacement of the regressive regime by the transgressive one has also changed the situation on the coasts with mud flats. Because of the gentle offshore slope (on the order of 0.0001), there is passive flooding of the coastal area. This pattern of flooding is not associated with any change of profile of the coastal zone or significant redistribution of the coastal deposits. Rise of the sea level not only leads to land submergence, but is also associated with a rise in the groundwater level, groundwater salinization, and marsh development in the coastal lowlands. Today Kirov Bay is again filled with water, and its contours are about the same as before the regression of 1929. In the area of Kilyasi Spit (northern Azerbaijan) the flat depositional platform formed in the period of the sea-level drop in the 1940's was flooded or marshy. Widespread lowland areas were flooded in the northern Caspian Sea on both sides of the Volga delta; the zone of flooding includes pastures, roads, and man-made structures. This same phenomenon could also be observed in some areas of the eastern Caspian: *e.g.* in the vicinities of Eralievo, Krasnovodsk, and along the southern side of the Cheleken Peninsula.

Under conditions of somewhat steeper slopes (0.0005–0.001) of the offshore gradient, and at certain distance from the shore, with sea-level rise a coastal bar is formed in the zone of wave-break; it is separated from the shore by a wide shallow area. This bar is gradually being transformed into a barrier. It is usually built of sand and shell material produced by erosion of the upper offshore slope in the process of transgressive reconstruction of the shore profile. The main morphological indicator of transgressive development of this barrier is that it is moving onto the shallow area (lagoon) and is pushing it landwards. Illustrations of this type of evolution of the coastal zone are abundant along the eastern Caspian Sea coast (Sandy Cape, seaward of Kenderly Spit, and along most of the southeastern coast).

Many changes are provoked by the Caspian Sea rise on the depositional coasts that have even higher inclinations of the offshore slope (0.005–0.01) and experience stronger wave impact. As noted earlier, the regressive regime was marked by accumulation of sediments on practically all coasts. Under fall of the sea level, accumulation took place as a result of the reshaping of the lower

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Figure 2. Types of Caspian Sea coasts. (A) regressive period, *i.e.* until 1977: (1) erosion, (2) erosion with abandoned cliff, (3) erosion-depositional coast, (4) depositional coast with beach, (5) depositional coast with lagoon, (6) mud flats formed by wind surges, (7) delta; (B) transgressive period, *i.e.* after 1978: (8) erosion, (9) erosion-depositional coast, (10) depositional coast with beach, (11) depositional coast with lagoon, (12) wind surge mud flats, (13) delta, (14) regions of transgressive subsidence.

and middle offshore slope which led to the transportation of sediments from the sea floor towards the land. This intensive landward transport of sediments suppressed the longshore drift to a certain degree (LEONTIEV and VELIEV, 1990), though the trend to the longshore drift continued in the long run. Input of the sea floor material promoted accretion of the prograding shores, but depleted reserves of loose material on the bottom, a process that finally resulted in a deficiency of sediments in the coastal zone and erosion of many recent and ancient aggradational features.

With rise of the Caspian Sea level erosion of the depositional coasts intensified. Under the transgressive regime the offshore zone is reshaped as well. However, this mostly applies to its upper part near water's edge, and is associated with erosion of the frontal parts of the coastal accretional features (where the offshore slope is relatively steep). Alternatively a beach ridge appears near water's edge and is gradually transformed into a barrier backed by a lagoon with further rise of the sea level. In this case the lagoon is affected by overwash and a landward rise of the groundwater surface.

The formation of lagoon shores of this type under the recent sea-level rise is evident in many portions of the Daghestan and northern Azerbaijan coasts (the western Caspian Sea). Thus, for example, in the coastal area south of Caspijsk (where the offshore slope is on the order of 0.005) during the recent regression a gently sloping coastal plain was formed and was bounded by a wide and very gradually sloping sandy beach. During the current sea-level rise, a recent beach ridge was formed along water's edge (1.0–1.5 m high and 30–60 m wide) with a narrow and steep seaward slope (the present beach). In the very beginning of the transgressive period (the first 2–3 years) the beach ridge was from time to time backed by an ephemeral lagoon filled by water during stormy conditions. In fair weather periods it became completely dry. However, later with continued rise of the water level, the lagoon is gradually becoming wider and has acquired stability; this was also helped by a rise of the groundwater surface. In 1990 the lagoon was 0.5–0.8 m deep and up to 25 m wide, and covered nearly the whole surface of the recent regressive coastal terrace of 1940. In the process of the sea-level rise the beach ridge generally maintained its former parameters but was gradually advancing onto the lagoon and creating the effect of shore retreat. Several instrumental surveys in the period 1981–1990 have documented the shrinking of the recent coastal terrace by 200 m in width in the last decade (Figure 3). One can expect further retreat of the shoreline under continued transgression.

A similar shore pattern is found along the northern coast of Azerbaijan that is now paralleled by many strips of lagoon and swamp vegetated by water herbs and shrubs. The newly formed beach ridges are built of bottom material that is coarser grained than found on the regressive coastal terrace (NIKIFOROV and RYCHAGOV, 1988). Change to the transgressive regime was associated with the disappearance of wide (up to 150 m) sandy beaches that existed there only one decade ago and which were backed by ridges of active coastal dunes. By today, most of the eolian features have become stabilized and vegetated due to lower input of sand resulting from beach shrinking and to rise of groundwaters (providing sources of moisture).

Certain Daghestan and northern Azerbaijan coasts that have higher inclinations in the coastal zone (up to 0.01) usually possess shore-attached barriers built of shells; these barriers are about 1.5 m high and have asymmetric profiles, with clear signs of landward migration onto the recent coastal terraces. The process of migration is rather rapid, so that shrub vegetation of these terraces often emerges in a living position from beneath this barrier on its seaward side. Generally there is no backbarrier lagoon, because in these areas the land slopes are rather steep and well above sea level.

Finally, if the inclination of the shore zone is over 0.01 there is very active erosion of the Holocene aggradational features, resulting in significant retreat of the shoreline. The development of the coasts of this type corresponds closely to the scheme of coastal zone change following the "Bruun rule" (BRUUN, 1962). With rise of sea level the zone of wave action starts to involve the seaward part of aggradational features that have higher slope inclinations as compared to the offshore slope. Due to the steep slopes in the immediate littoral zone, the shore is reached by larger waves without loss of energy; this explains the very active erosion of the front of aggradational features and beaches. According to the Bruun theory, erosion of the seaward portions of the depositional coast and consequent retreat of the shoreline are associated with simultaneous accumulation of sand and accretion of the bottom

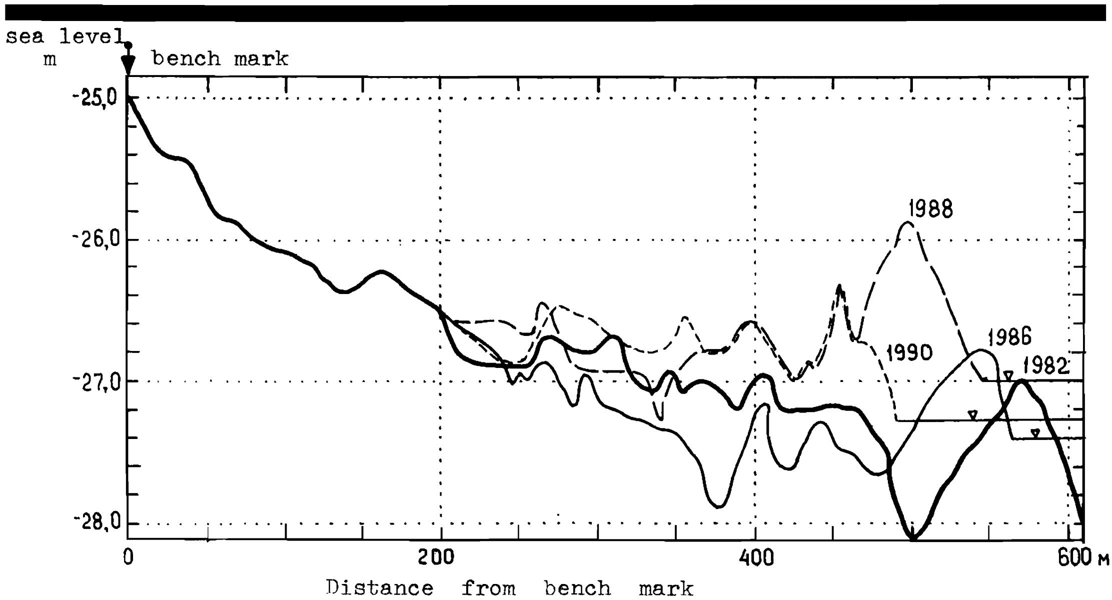

Figure 3. Transects of the subaerial part of the coastal zone 6 km south of Kaspijsk Town.

in the outer surf zone. It is assumed that the amount of material eroded in the upper coastal zone equals that accumulated in its outer part. An example of such pattern of development of the coastal zone is provided by an area north of Makhachkala (Karaman area). There, rise of the sea level produced intensive wave erosion of the seaward slope of the Holocene sandy coastal flat; a cliff up to 1.5–3.0 m has developed. The shoreline in this area retreats at rates about 10–12 m/year. Some coasts of Daghestan and Azerbaijan are showing rates of erosion of the Holocene marine terraces of up to 15–20 m/year, and in some cities (Makhachkala, Kaspijsk, Derbent, Lenkoran) many residential and industrial structures are threatened.

Replacement of the regressive regime by a transgressive one has influenced also the erosional coasts of the Caspian Sea. This type of coast occurs along the eastern Caspian Sea (Mangyshlak Peninsula, north of the Karabugaz Gulf, Cheleken Peninsula, *etc.*) and in some parts of the western coast (Apsheron Peninsula, Gobustan capes, *etc.*). The former sea-level drop has left marine cliffs in many coastal areas beyond reach of waves. In front of them benches and beaches were formed; less often there were narrow depositional terraces consisting of series of small beach ridges. Thus, on the northern coast of the Mangyshlak Peninsula built of Miocene and Paleogene sandy-clay deposits, there was erosion of some prominent capes. Linear stretches and erosional bays of peninsula were bordered by rather wide depositional terraces.

On the western coast, in Gobustan the erosional capes (often big mud volcanoes) built of volcanic breccia, clays and loams of early and late Quaternary age, are bordered by a dense clay bench that is almost bare of sediments. Before 1929 these capes were being actively eroded with development of cliffs up to 7–10 m high. Regression of the sea stopped the erosion, because storm waves were dissipated on the bench surfaces. Some parts of the coasts of Daghestan were well protected from wave erosion by the ridge relief in the nearshore zone. Submarine ridges built of the Pliocene limestones were protecting the shores until recently.

Under the modern rise of the Caspian Sea level the benches and ridges are flooded, and, particularly during surges, storm waves reach the cliff base. In the areas where the cliffs were protected by the earlier depositional terraces there is erosion of the terraces and active reworking of their sediments, partly shifted onto the outer surf zone and partly removed by longshore transport. In all cases one can note a more active wave impact on the coast above the water's edge and rapid erosion and destruction of the land.

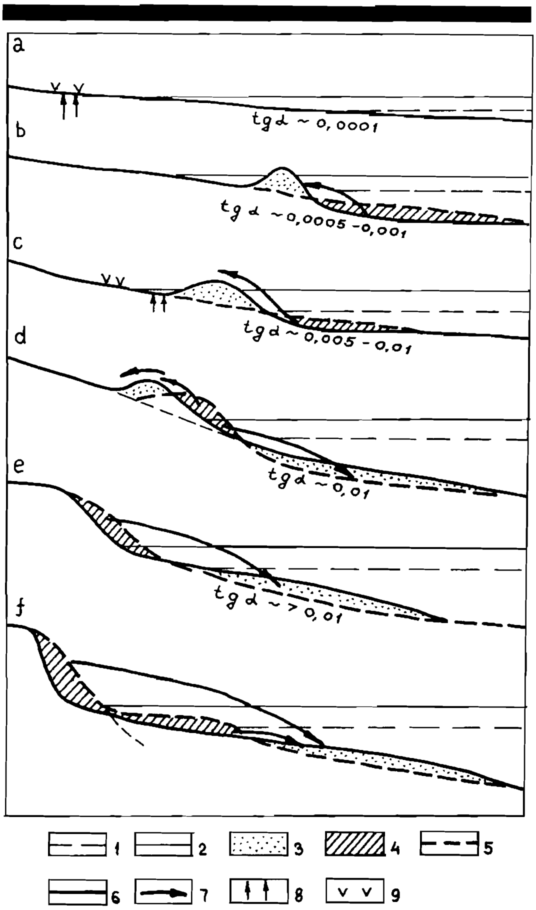

Figure 4. Model of transgressive evolution of the Caspian Sea coastal zone (explanations in the paper): (1) regressive sea level, (2) transgressive sea level, (3) accumulation of sediments, (4) erosion lens, (5) former profile of the coastal zone, (6) modern profile of the coastal zone, (7) transport of erosion materials, (8) rise of groundwater, (9) marshes.

EVOLUTIONARY MODEL OF THE COASTAL ZONE UNDER SEA-LEVEL RISE

The recent rise of the Caspian Sea level has thus significantly modified the dynamics of all coastal types identified. Evolution of the world's sinking coasts is not universally uniform depending on inclinations of the offshore slope. Publications on the coastal dynamics of sea-level rise generally employ the model of BRUUN (1962). However, this scheme was developed with data from the U.S. Atlantic coast and is not universally applicable, mostly because it ignores differences in inclination of the onshore and offshore slopes of the coastal zone. Conceptual models, as well as direct observations in the Caspian coastal zone, are demonstrating different variants of the coastal zone development under sea-level rise (LEONTIEV, 1988; IGNATOV *et al.*, 1989; KAPLIN, 1989, 1990).

On the gentlest, shallow shores, as was shown above, there is passive flooding of land without dynamic change of the coastal zone (Figure 4a). Such shores are not subject to significant wave action, because waves dissipate their energy on the gentle offshore slope well before the water's edge. Under higher inclinations and especially if the offshore slope profile has a sharp slope discontinuity the zone of wave break will be at some distance from the shoreline. In this case a longshore bar (and eventually a barrier) is developed in the surf zone, creating a lagoon (Figure 4b).

The most common pattern of shore evolution in the Caspian coastal zone (under inclinations 0.005–0.01) is erosion of the upper offshore slope, associated with wave reworking of deposits in this zone and pushing sediments towards shoreline where a barrier beach is formed, backed by a lagoon (Figure 4c). If there is no lowland behind the beach ridge (barrier), there is naturally no lagoon. Inclinations are somewhat greater in this case, and besides the erosion in the offshore slope the beach ridge is shifting towards land. This is actually another variant of evolution of the coastal zone that is shown by Figure 4d.

Under still steeper slopes (over 0.01) the zone of erosion is shifted even higher up the coastal profile and landwards, and involves the frontal portion of the Holocene aggradational features (Figure 4e). Coming back to the Figure 4c situation, it is clear that the new offshore slope profile formed under the sea-level rise is "lower" than the previous profile of equilibrium (*i.e.* the deeper the sea, the stronger the wave action), and therefore promotes erosion of sea floor near the shoreline. Under steeper slopes (Figure 4e) the developing profile differs from the original one, above all, by greater landwards shift accounting for its erosion, and besides by the lower position of the original offshore slope due to its steepness as compared to the one to be developed in the course of transgression. Therefore, in Figure 4e the offshore slope is filled up to the equilibrium state by way of accumulation of the material produced by erosion of the coast. Thus, the developing profile consists of an upper erosional part and of a lower accumulation part, *i.e.* it fully agrees with Bruun's scheme.

The above variants of transgressive coastal development suggest that the steeper the slope, the more the zone of erosion is shifted up the profile and towards the land. The area of accumulation of the deposits produced by the wave regime is changing correspondingly.

Finally, the last profile (Figure 4f) illustrates the evolution of a former erosional coast that became inactive in the regressive period due to formation of the depositional terrace. In general, in this case the evolution also follows the Bruun model. The zone of erosion is just at the water's edge; the depositional terrace is reworked, and the material is transported onto the offshore slope. With erosion of the depositional body more and more cliffs are formed, and with time active destruction of the bedrock slope begins.

CONCLUSIONS

Analysis of Caspian Sea coastal dynamics demonstrates an imperfect agreement of the regressive and transgressive marine regimes with the cycles of coast evolution. As established by many authors, the regressive regime in general corresponds to an accretionary (prograding) cycle. However, the erosion of aggradational features started in the 1960's while the sea level was still dropping. One of the reasons for this active erosion could be "beach starvation" due to human economic activities: construction of water reservoirs on rivers and development of irrigation networks that have reduced river discharge and resulted in deficiency of sediments in the coastal zone. At the same time there is a "natural" explanation why the accumulative cycle changed to an erosional one. Drop of the sea level, the same as during a transgression, is associated with reshaping of the offshore slope profile and with its erosion. However, during regression the zone of offshore slope erosion shifts seaward, not landward, involving parts of the outer slope where the material is of finer grain size. With time, the supply of the sediment fractions that can be transported by waves up the slope and that can build accreting features are exhausted.

This is a regular process but what is striking is that the cycle of development of the coastal processes with a certain trend is rather brief. It took only about 30 years (from 1929 to 1960's) for completion of the process of coastal aggradation under continuous regression. It appears to be necessary now to monitor the duration of the current erosional development of the Caspian Sea coasts under the sea-level rise.

The rates of the Caspian Sea coastal change are much higher than on the coasts of the World Ocean but their fundamental similarity is undoubted. In view of that, studies of the Caspian Sea coasts can have, besides regional significance, a general conceptual value and can be useful for simulation of the laws pertaining to the coastal zone of the World Ocean.

ACKNOWLEDGEMENTS

The authors express their sincere thanks to Prof. R.W. Fairbridge who has reviewed the manuscript and suggested valuable improvements. Many thanks also to Prof. M. Schwartz for his encouragement.

LITERATURE CITED

Barth, M. and Titus, J.D., (eds.), 1984. *Greenhouse Effect and Sea Level Rise.* New York: Van Nostrand Reinhold, 325p.

Bird, E.C.F., 1985. *Coastline Changes: A Global Review.* Chichester, England: Wiley, 219p.

Bruun, P., 1962. Sea level rise as a cause of shore erosion. *Journal Waterways and Harbours Division.* 88(WWI), 117–130.

Ignatov, E.I.; Kaplin, P.A.; Lukyanova, S.A., and Solovieva, G.D., 1990. Problems of the Caspian Sea coasts evolution under sea level rise conditions. *A Guidebook for Field Excursions of the International Symposium "Transgressive Coasts: Studies and Economic Devleopment". Baku, USSR. 15–21 September 1990.* Moscow, pp. 126–127.

Ignatov, E.I.; Lukyanova, S.A., and Solovieva, G.D., 1989. Current state of the Caspian Sea coasts. *In: Recreational Resources of the Caspian Sea: Problems of Use and Conservation.* Moscow: Nauka, pp. 13–18 (in Russian).

Kaplin, P.A., 1989. Shoreline evolution during the XX century. *In:* Ayala-Costanares; Wooster, W. and Yanes-Arancibia, A. (eds.), *Oceanography-1988.* Mexico City: UNAM Press, pp.59–64.

Kaplin, P.A., 1990. Practical problems for coastal submergence in the light of secular trends. *In:* Paepe, P., *et al.* (eds.), *Greenhouse Effect, Sea Level and Drought.* Dordrecht: Kluwer, pp. 385–393.

Leontiev, O.K., 1988. Problems of the Caspian Sea level and stability of the Caspian Sea shores. *Vestnik MGU. Ser. Geogr.,* N I, pp. 14–20 (in Russian).

Leontiev, O.K.; Maev, E.G., and Rychagov, G.I., 1977. *Geomorphology of the Caspian Sea Coasts and Floor.* Moscow: MGU, 208p. (in Russian).

Leontiev, O.K. and Veliev, Kh.A., 1990. *Western Coasts of the Caspian Sea (a Guide-Book for Field Excursions of the International Symposium "Transgressive Coasts: Studies and Economic Development."* Baku, USSR: 15–21 September 1990). Moscow, 165p.

Nikiforov, L.G. and Rychagov, G.I., 1988. Evolution of the Caspian shores in the current sea level rise situation. *Vestnik MGU. Ser. Geogr.,* N 2, pp. 47–51 (in Russian).